research review

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Magnetooptical Laser

MAX SWERDLOW, Solid State Sciences Division, AFOSR

Magnetic field has long been a valuable research parameter in many areas of science, but only recently has the need for very intense continuous fields stimulated widespread cooperation in the difficult problem of generating such fields and, more importantly, exploiting them. The new National Magnet Laboratory (NML) sponsored by AFOSR at MIT is a direct consequence of this increased need and interest. The NML is unique in both the intensity of the continuous magnetic fields it provides and in the extreme flexibility of its operation. The technical staff carries on a vigorous program of research in solid-state physics using intense magnetic fields and other advanced scientific equipment. In addition, the facilities of the NML are made available to qualified researchers from other organizations devoted to basic-research studies in diverse fields of science.

Recently, a group of scientists at the Lincoln Laboratory of MIT, in collaboration with Dr. Benjamin Lax, Director of the NML, obtained laser* action for the first time in an indium-antimonide diode.[1,2,3,4]

Just a year ago, within a month of each other, three laboratories, General Electric, IBM and Lincoln Laboratory,[5] announced the successful operation of the first semiconductor laser made of gallium arsenide. Since then, this dark horse of the laser family has made tremendous strides and shows prospects as a very versatile and promising device for coherent radiation in the infrared and optical regions of the spectrum. This does not mean that the semiconductor makes the ruby or the gas laser obsolete. On the contrary, it complements the others and, at the same time, possesses unique properties which distinguish it from the others. Although the semiconductor laser is not intrinsically a high-power device like the ruby or the glass laser, its power capacity as a continuously operating coherent light source of more than one watt exceeds

(Continued on P.6)

** The terms, laser and maser, are used interchangeably to describe new quantum electronic devices which generate coherent electromagnetic radiation from the microwave through the infrared and into the optical regions of the electromagnetic spectrum. The words have evolved as acronyms of the phrases, "light amplification of stimulated emission of radiation," and "molecular amplification of stimulated emission of radiation." It is preferable to use the term, laser, to describe the devices which emit infrared and optical radiations, and maser for those which emit in the microwave and millimeter regions of the spectrum.*

research review
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from the Editor:

The OAR Research Review is the product of many minds. From its inception a few years ago as the AFOSR Activity Report to Hq ARDC, to the new format beginning with this issue, it has sought to provide a channel for Air Force scientists and contractors engaged in research to bring the results of their research to the attention of potential users. That it has been successful in this regard is attested to by the steadily increasing requests from both private and government individuals and research organizations to receive this publication.

To more effectively meet this growing need for bringing the fruits of OAR research to the user, particularly the technologist, the OAR Research Review has taken on a new dress. Its objective will remain the same. However, it will be published monthly instead of semi-monthly in an effort to provide additional time for its contributors. The arrangement to have the Government Printing Office prepare all reading material in two columns and use a better quality paper, without an increase in over-all cost, will result, we believe, in a format much more pleasing to the eye. And the feature, "OAR PROFILES," will give our readers an opportunity to become acquainted with the OAR scientists and contractors who have contributed so much to the achievements of Air Force research.

We have been fortunate in the past in receiving excellent cooperation from our counterparts in the field: Mr. David L. Arm at AFOSR, Mr. LaVerne E. Woods at AFCRL, and Major George Molnar at ARL. With their continuing cooperation assured, and with the sustained support of OAR scientists and of the RTD Laboratories performing OAR-funded research, we expect the OAR Research Review to achieve its objective of becoming an even more readable and scientifically informative publication than it has been in the past. In this role, the Review will continue to support OAR in its affirmed objective of accelerating the exchange of scientific and technical information resulting from the OAR research program throughout the Air Force, DoD, and the scientific community.

JACOB SEIDEN
Editor

improved accuracy in life testing

MAJOR JOSEPH P. MARTINO
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A problem of increasing importance in the design of aerospace vehicles is that of life testing of components. In order to be able to predict the effectiveness of the vehicle during the design phase, it is necessary to be able to predict the failure behavior of the many components and subsystems in the vehicle. Furthermore, during production, it is necessary to be able to assure that specified lifetimes are being met by the components. For both these purposes, life testing is an accepted tool.

In principle, life testing is simple. A sample of the items (say, vacuum tubes) is selected, and the items in the sample are operated at the design conditions continuously until failure. Failure may mean total cessation of function, or it may mean only that the item no longer performs within the specifications. In any case, time-to-failure is recorded for each item in the sample, and statistical analysis of the sample data provides information on the expected life.

For many types of items, it is assumed that time-to-failure is governed by the Weibull Distribution (1):

$$f(t) = (m/a)\, t^{m-1} \exp(-t^m/a),$$

which gives the probability that failure will occur in the time interval (t, t + dt) or, more loosely, that failure will occur at time t. This distribution is assumed for the excellent reason that in many cases it seems to work and give useful results. There is, however, no theoretical reason which justifies its use. In the Weibull Distribution, the parameter m is called the "shape parameter," and varying it permits making a good fit to many slightly different distributions. The parameter a is related to the "mean time to failure," and in the case of m = 1, a is the mean time to failure.

In general, for testing a specific component, it is assumed that m is known (i.e., that the shape of the failure distribution for the component is known) and that it is necessary to determine a for the specific lot of components from which the sample is taken. This parameter is never determined exactly, of course, and only a statistical estimate of it is made. Thus it is necessary to be able to give a statement of the precision of the estimate, that is, a statement of the probability that the estimate differs from the true value of a by more than a certain amount. More precision is obtained by increasing the sample size, or by increasing the length of the test. That is, one may test until a fixed number of items have failed, or one may test for a fixed length of time. To obtain more precision, one may increase either the fixed number of failures, or the fixed length of time. This generally requires a larger sample, to guarantee that the fixed number of failures occurs in a reasonable time, or that a reasonable number of failures occurs in the fixed time.

The procedure of testing for a fixed length of time is more convenient from a production standpoint, as it provides information at fixed intervals during the production process. In this case, it can be shown that a "good" estimate of a (the maximum likelihood estimator) is given by:

$$a^* = (1/r)\left(\sum_{i=1}^{r} x_i^m + (n - r)\right) T^m$$

where T = fixed time of test

$x_i = t_i/T$, time to failure of the ith item

n = number of items in the sample

r = number of items failing in time T

The mean square error of this estimate is given by

$$E(a^* - a) = T^{2m}[n^2 V(1/r) + (b^2 - q/p^2) E(1/r)] + T^{2m}[nE(1/r) - q/p - 1]^2$$

where E(.)= expected (average) value of (.)

V(.)= variance of (.) (i.e. the expected value of the square of (.)

$b = a/T^m$

p= probability that exactly r failures occur

$q = (1-p)$

and the other symbols are as in the previous equation.

It is thus apparent that the mean square error of a^* involves the moments of $1/r$, that is, the expected values of powers of $1/r$. Exact computation of these moments is extremely laborious. Thus until quite recently, it was necessary to use approximations to these moments. Tables of such approximations are given in (2), among other places.

However, a recent result announced by Dr. Zakkula Govindarajulu, of Case Institute of Technology, working under Grant AF-AFOSR 62-72, greatly simplifies the problem. His paper, "Recurrence Relations for the Inverse Moments of the Positive Binomial Variable," present formulas which make possible the computation of any moment, given any other moment. That is, given the first moment, it is possible to compute the second and then, using the second, the third may be computed, etc. The computations using the recurrence relations are much more rapid than direct computation of each moment. Furthermore, he is able to show that errors propagated by the repeated use of the recurrence relations are bounded and that, in some cases, no error at all is propagated. Finally, computations using his method are much more accurate than the previously used approximations. Thus his results can greatly simplify the work of statisticians involved in life testing, by permitting easier and more accurate determination of the precision of the estimates of mean time to failure derived from life tests of samples.

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demarcation between upper atmosphere and space

NORMAN SISSENWINE, Aerospace Instrumentation Laboratory, AFCRL

"Where should the line of demarcation be made between the upper area of Airspace and the lower area of Outer Space? In what manner can a boundary line be established with due regard to capacity for policing invasions or trespasses across this boundary line?"

This question was directed in a recent letter from the law firm, Hyman, Hayman and Harris of New York to Norman Sissenwine of AFCRL. The firm raised the question in an attempt to arrive at a legalistic interpretation for the Congress of the International Astronautical Federation and the International Institute of Space Law. The question, of course, has no firm legal answer. But Sissenwine, as cochairman of the U.S. Committee on the Extension of the Standard Atmosphere, is exceptionally well-qualified

to discuss the matter from a technical viewpoint. Excerpts from his correspondence with the law firm are quoted below:

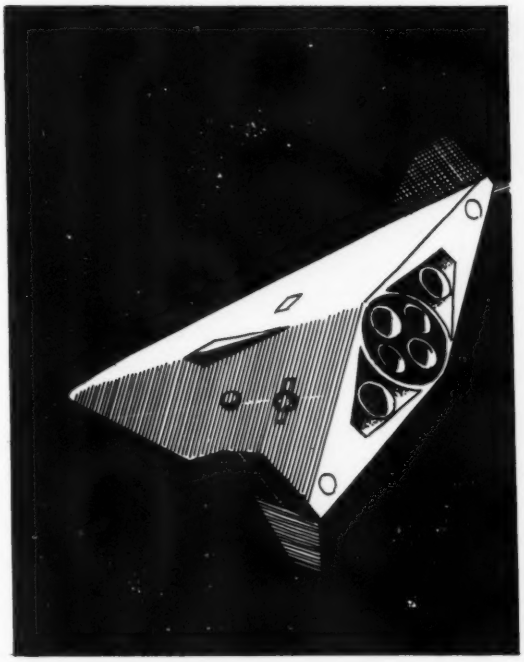
"The lowest altitude at which I believe the line of demarcation should be assigned is 100 km. I lean toward this altitude for the following reasons:

"Aerodynamic forces on most of the ballistic re-entry, lifting re-entry, and boost-glide orbital aerospace vehicles can generally be neglected at altitudes above 100 km. (This may vary from 80 to 120 km, depending upon the vehicle concept; but I believe 100 km is a good nominal altitude to use.) Also, I believe multiple orbiting of satellite vehicles below 100 km is not very feasible due to aerodynamic heating problems.

"The basic composition of the atmosphere, that is, the oxygen-nitrogen relationship, begins to change near this altitude. Specifically, it has been determined that dissociation of molecular oxygen into atomic oxygen should be depicted at an altitude of 90 km in the Standard Atmosphere which is, roughly, the thermosphere.

"Atmospheric density in one of the major parameters of concern is the design of aerospace vehicles. Studies of the variability data have indicated seasonal and latitudinal departures approaching 75 per cent of standard density at altitudes of 60-70 km. However, almost all available data have indicated that, at some altitudes slightly above 90 km, the atmosphere has built in a self-compensation process so that density is nearly constant for all latitudes and seasons. Consequently, there can be a certain amount of confidence placed in the geometric altitude at which aerospace vehicles designed to respond to a density keyed to this altitude would remain at that altitude.

"The equations of motion of the atmosphere used by the meteorologists in relating temperature and pressure fields to the wind field can generally be assumed to hold to nearly 100 km; but above that altitude, other physical processes have important influence. This is also true for the speed of sound, coefficient of viscosity, kinematic viscosity, and thermal conductivity which may depart considerably from the physical relationships valid at lower altitudes as inferred by the fact that tables of these parameters are not presented above 90 km in the Standard Atmosphere.



"Meteors entering the atmosphere generally disintegrate at altitudes below 120 km, due to aerodynamic heating and drag, at which time they leave a visible and ionized trail. At higher altitudes, these atmospheric influences are insignificant. Most of the trails are observed below 100 km."

In spite of the many technical considerations mustered to favor a line of demarcation at about 100 km, Sissenwine recognizes that ultimately the line must be drawn arbitrarily. In a concluding paragraph, he notes:

"Of course an arbitrary altitude may be set anywhere between 100 and 200 km, or perhaps even as low as 90 km if one wants to key it to the break of the temperature lapse rate which takes place at the top of the mesopause isothermal layer."

Magnetooptical Laser

(Continued from P.1)

those of any other type. Its capability to be conveniently and easily modulated at very-high frequencies makes it an attractive candidate for application in the field of communication. The extremely small size of the unit and its high efficiency in converting electrical energy to coherent radiation make it an ideal source of a narrow band of energy for pumping lower-frequency lasers in the far and near infrared and the submillimeter regions in a manner analogous to that of the more conventional three-level maser in the microwave region.

Today there are actually three classes of masers which are being seriously investigated in the laboratory. The first, the direct-transition maser, which has already been successfully operated using a gallium-arsenide diode, is receiving the greatest attention.[5] The indirect, or the two-boson maser,[6] has been considered theoretically and attempted experimentally; however, it has not yet met with success. The third class may be categorized under the title of magnetooptical masers and, of course, includes the cyclotron-resonance maser which is the first of this type proposed.[7] A fourth, which as yet has not been given serious consideration but has been discussed from time to time, involves the transition between impurity levels in a semiconductor. It is, in some respects, analogous to the gaseous-optical maser in which metastable levels are involved.

Each of the devices mentioned may be pumped either electrically or by a strong optical source such as a flash lamp or another maser with an intense emission line. In any coherent oscillator, three basic phenomena have to be considered. The first requirement is that a mechanism be provided for inverting the electron population in a higher-energy state relative to a lower one. Then, when subsequent stimulated emission is induced, the second requirement is that the energy of the stimulated emission overcomes the losses incurred in the device. These losses in a semiconductor involve bulk and surface phenomena. The third requirement is a resonance structure for confining the electromagnetic energy and for providing a means of achieving coherence and the necessary gain for maser oscillations.

Since the development of the gallium-arsenide diode maser in 1962, a number of other semiconductor-laser diodes have been successfully operated at infrared wave lengths out to 3.1 microns. In several of these, it was observed that the threshold current was reduced when magnetic fields were applied. Prior to the advent of the diode laser, early theoretical considerations of possible lasers involving the use of high-magnetic fields in indium antimonide indicated that they would operate further out in the infrared at about 5 microns. The operation of such a laser is a consequence of the quantization of the energy levels of electrons in the conduction band and holes in the valence band in a magnetic field. This means that the energy levels, which at zero-magnetic field are continuous in energy, now become grouped into a set of discrete states. This phenomenon then has the effect of enhancing the absorption of infrared waves when the wave lengths correspond to those energies separating these discrete states of the conduction and valence band, respectively. Conversely, emission and, in particular, stimulated emission, as in a laser, is also enhanced by the phenomenon of quantized magnetic levels. Therefore, the threshold curve required to produce laser action, as in a semiconductor-diode laser, will be reduced. In other words, it will be much easier to make such a diode produce coherent light with a magnetic field than without it.

Until recently, this was a theoretical concept well founded on the knowledge obtained from magnetooptical phenomena. It was discovered that no coherent radiation was emitted until the maghetic field exceeded 15,000 gauss. The threshold current, quite high at this field, was reduced by a factor of 4 when the field reached 50,000 gauss and above. In addition to lowering the

threshold, the magnetic field also made it possible to vary the output frequency of the laser over an 8 per cent band width from about 5 microns to about 4.6 microns when a field of 100,000 gauss was reached. This is the largest magnetic shift observed so far in any laser. Thus, an optically pumped interband magnetooptical laser which should be versatile, compact, efficient and magnetically tunable takes its place alongside the promising quantum electronic techniques and devices which have preceded it only so recently.

For scientific investigations, the laser has already become one of the most exciting and productive tools since the advent of microwaves. A good deal more about the basic optical and infrared properties of a variety of solids, liquids and gases has been learned because of the laser as well as with it. Particularly in the area of nonlinear optics, a whole new field of physics has been initiated. Raman spectroscopy, which is an older field, has received a new lease on life. Breakdown of gases by optical fields presents some new and interesting problems. Fundamental gravitational and cosmological experiments have been proposed. Seismology has a new tool in the gas laser. Ultrahigh-resolution spectroscopy is now possible over a wide range with either the gaseous or the semiconductor lasers as sources. This is particularly intriguing if external parameters, such as pressure, temperature or high magnetic and electric fields, can tune the spectral resonance through the laser line, or the latter through the resonance.

On the practical side, a number of laser applications have been outlined, for example, ultrahigh-resolution radars for reconnaissance and detection. The narrow beams possible with coherent sources and associated optics cannot be matched with microwaves. Furthermore, the small physical size of the laser system is a decided advantage, and range resolution is much greater. Q-switched lasers already operate in the tens of nanoseconds, but semiconductor lasers have theoretical limits of nanoseconds. Very likely, range resolution in terms of one foot is foreseeable. As higher-power lasers become available, not only will welding, micromachining and microsurgery become attractive approaches for special practical tasks, but also optical radar and communications will be possible over longer ranges. The nonlinear phenomena and the physics of interaction of high-energy beams with matter will also enter a new regime as a consequence. As the frequency of the laser is extended, new applications will develop. The far-infrared and submillimeter regions and probably the ultraviolet spectrum will be reached. The latter will have an impact on chemical reactions at selective frequencies. If this is realized, the commercial possibilities can be significant.

On the technological side, a blue-green laser can have importance for underwater transmission. Laser technology could very well open a new and extraordinary wide band for communications. For example, at the red end of the visible spectrum, the frequency of wave radiation is approximately 4×10^{14} cycles per second. A one-per-cent band in this region of the electromagnetic spectrum, with its inherently higher frequency, has a width of 4×10^{12} cycles per second. Assuming a carrier frequency of, say, 2×10^{3} cycles per second, one billion telephone conversations could be transmitted simultaneously.

It is a temptation to speculate indefinitely, but that should not be necessary. Laser research is still in its infancy; no one can predict with certainty where the really important applications lie, nor which of these is to prove profitable economically. One thing is certain; the laser will make an important contribution to science and technology. Because the laser is a product of sophisticated scientific thinking evolving from classical electromagnetic theory, modern quantum statistics, and the techniques of microwave spectroscopy, and not a product of serendipity or edisonian inventiveness, continued advances and fuller development of this remarkable modern phenomenon will emerge mainly through continued research in the three essentials of laser action, namely, suitable materials (large, nearly perfect single crystals), appropriate excitation

(pumping) sources, and designs that promote efficient stimulated emission.

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Weather FORECASTING SKILLS

IRVING I. GRINGORTEN

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In planning activities based on the weather, we often accept forecasts without knowing if they are the best for our specific operations. There is a great need for a satisfactory method for judging the skill of one forecaster against that of another. This problem was discussed by AFCRL scientist Irving I. Gringorten in paper, "Verification to Determine and Measure Forecasting Skills," presented at the annual meeting of the American Meteorological Society in January.

Gringorten defines forecasting skill as the forecaster's ability to recognize a departure from average climatic conditions in a locality. In all areas of the country we know from past records that, during given months, there will be so many cloudy days, so many rainy days, so many days with temperatures below freezing, and so on. We also know the frequency with which one cloudy day will be followed by another, and that below-freezing temperatures will be followed by an abrupt rise in temperature. Knowledge of average climatic frequencies--whether derived from precise statistical tables or simple experience--have great operational value and are useful to the public at large. The merchant knows that he should stock so many umbrellas, the ski-area manager that he should expect so many weeks of snow, and the baseball commissioner that so many games must be rescheduled because of rain. The specific predictions of the forecaster are not necessary for this useful information. But, whether the weather changes frequently or tends to persist, it becomes additionally useful to the citizenry when the forecaster states what kind of weather has an added chance of occurring. It is precisely at this point that the forecaster's art becomes a force. The skill of the forecaster is demonstrated by his ability to recognize when the probability of an event, such as rainfall, is sharpened above its climatic frequency.

This way of looking at forecasting skill is quite different from that ordinarily considered by the general public. It is usual for people to think of forecasting skill as a measure of the general accuracy of forecasts per se. Gringorten points out that, in the Sahara Desert, anyone can forecast sunshine each day with an accuracy of better than 99 per cent. We, of course, cannot say that a forecaster making predictions in the Sahara is superior to a forecaster in Boston simply because the Sahara forecaster is more often correct.

Statistical Theory of *plasmas*

1/Lt STUART D. JORDAN, Mechanics Division, AFOSR

One of the major problems confronting plasma physics is the derivation of a suitable kinetic equation to describe the time dependence of the distribution function of the particles in the plasma. Once one has the correct kinetic equation for a particular range of plasma properties, it is comparatively straightforward to obtain the transport coefficients (thermal and electrical conductivities, viscosity where appropriate and diffusion coefficient) as well as the equations for magnetohydrodynamics which are the counterpart of the Navier-Stokes equations for flow of an electrically nonconducting fluid.

In 1946, Bogoliubov (1) published a scheme for obtaining kinetic equations for different systems, proceeding along the following general lines. He starts with the Liouville equation of statistical mechanics, which is equivalent to Hamilton's canonical equations, that in turn express Newton's laws of motion. Expressing the Liouville equation as the now well-known BBGKY hierarchy, an equivalent system of equations, he expands the hierarchy in a certain way, finally synchronizing the distribution function for all N particles to the single particle distribution function F^1. The result is a partial differential equation, the kinetic equation, which takes the form

$$\frac{\partial F^1}{\partial t} = A[F^1]$$

where the bracket indicates that A is a function of F^1 only, and does not depend on the two-or-more particle distribution functions F^2, F^3, etc.

The trick lies in how one performs the expansion. A straightforward expansion of the BBGKY hierarchy fails because secularities (terms which grow without limit as time increases) appear in the expansion for times greater than one collision. The appearance of secularities is due to the omission of terms accounting for physical processes persisting after one collision time which one might hope would cancel the secularities.

Bogoliubov's method for eliminating the secularities was to look only at what has occurred after a long time, i.e., to ignore short-time processes with all their inherent difficulties and guarantee the appearance of a kinetic equation. By suitable juggling, he came up with a mathematical procedure which yields the familiar Boltzmann equation for neutral gases and a widely accepted kinetic equation for low-density, fully ionized plasmas which is obtained on more empirical grounds by another procedure. In effect, Bogoliubov solved the problem by overstepping it.

Recently, Professor Ed Frieman at Princeton University and Dr. Guido Sandri, now at the Aeronautical Research Associates of Princeton (ARAP), developed a different procedure for yielding kinetic equations for physical systems, again starting with the Liouville equation. The method is somewhat more straightforward than Bogoliubov's, and brings in more physics earlier in the procedure. In Frieman's method, both fast and slow relaxation processes are accounted for, so that in the initial expansion, terms appear naturally to cancel the secularities. Frieman's method has led to both kinetic equations obtained previously using Bogoliubov's technique.

Working under AFOSR support, Dr. Sandri of ARAP has further simplified this procedure and derived a very general kinetic equation of which the right-hand side (the "collision" integral) assumes a special form consisting, in turn, of the product of four factors each of which has physical meaning and can, in principle, be evaluated for the particular system under study.

Dr. Sandri has also shown how to introduce the effect of triple or three-body collisions into the procedure for obtaining the kinetic equation for a particular system. These efforts, representing about two years work, have led to several papers in the open literature (2) (3) (4) (5) (6).

There are two compelling reasons why this work is important. To begin with, the kinetic equation used to describe fully ionized plasmas, called variously the Vlasov or Fokker-Planck equation, seems all right to describe the macroscopic behavior of many low-density, fully ionized plasmas where long-range forces dominate the behavior. It has, however, one serious shortcoming. No provision is made (without artificially introducing added terms) to account for short-range repulsive forces which must be present if the plasma is to be kept from collapsing. The rigorous derivation made by Dr. Sandri introduces these effects naturally in a fundamental step long before the kinetic equation appears.

Finally, a most compelling reason for supporting this work from the Engineering Sciences' viewpoint is that most practical and proposed MHD devices for boundary-layer control, power generation, etc. involve only partially ionized plasmas. Here there is no kinetic equation whatsoever. Using a somewhat simplified, yet rigorous procedure, as set forth by Frieman and Sandri, a first step can be taken toward obtaining a rigorous equation for this case. The engineers can then make it tractable by the usual order-of-magnitude analysis of the terms which appear.

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(Because of an unexpectedly heavy demand, Dr. Sandri has exhausted his entire supply of reprints of references (5) and (6), having distributed more than 250 copies in this country and abroad.)

A NEW THEORY OF NONLINEAR NETWORKS

MAJOR B. R. AGINS, Applied Mathematics Division, AFOSR

In recent years, engineering problems have led to the study of nonlinear networks, for which a general theory has not been available. For those electric circuits which can be represented by linear differential equations, there exists a rather complete theory set forth in several textbooks. However, circuits such as "flip-flop" have several equilibrium states, and can be described only by nonlinear differential equations. A nonlinear circuit is characterized by the nonmonotone nature of the voltage-current relation for resistors ("negative resistance").

Under the joint sponsorship of the Applied Mathematics Division, AFOSR and Thomas J. Watson Research Center, IBM, Drs. R. K. Brayton and J. K. Moser have developed a new, complete theory of nonlinear networks. ([1])

The networks considered are general RLC circuits in which any or all elements may be nonlinear. It is shown that the differential equations, under very general assumptions, have the form

$$L\ (i)\ \frac{di}{dt} = \frac{\partial P(i,v)}{\partial i}$$

$$C\ (v)\ \frac{dv}{dt} = \frac{\partial P(i,v)}{\partial v}$$

The function P(i,v), called the mixed potential, can be written directly from the circuit by a procedure which is given. P(i,v) describes the physical properties of the resistive parts of the circuit and can be used to prove stability under certain conditions. Several theorems on stability are proved and examples given to illustrate the results. A new theorem on the existence of periodic solutions of periodically forced nonlinear networks is proved.

The usefulness of the theory has been demonstrated by its application to a formidable problem. A large, repetitious nonlinear circuit containing tunnel diodes was analyzed by the methods of the theory. The analysis showed how the number of elements in a circuit joining at a particular place affect the stability of the circuits. Further application to distributed circuits is being considered.

(1) Brayton, R. K. and J. K. Moser, "A Theory of Nonlinear Circuits," to appear in the Quarterly of Applied Mathematics.

Natural Operating Areas for AIRCRAFT

OWEN W. WILLIAMS, Terrestrial Sciences Laboratory, AFCRL

There are many natural landing areas all over the world from which Air Force strategic and tactical aircraft might operate. These provide effective, secure and relatively inexpensive operational bases permitting the aircraft to disperse and to maintain emergency landing capabilities. Whether aircraft can use natural terrain depends on two interacting factors. These are aircraft design--wheel loading, tire pressure, and landing-gear configuration--and terrain features, such as strength, moisture content, roughness, and mechanisms of soil failure or displacement.

AFCRL scientists are seeking to define the relationship of these factors in order to predict the dynamic load deformation behavior of aircraft and the effects of varying terrain under all conditions. Rolling resistance theories for accelerating or decelerating loads, stress distribution between contact surfaces, extent of rut formation, remolding, compaction, and soil friction are all being investigated in the temperate, arid and semi-arid zones. AFCRL scientists have estimated that there are hundreds of flat land surfaces, previously thought to be unusable or inaccessible, capable of supporting fully loaded heavy aircraft.

Of the natural landing areas capable of supporting heavy aircraft, those holding most promise are dry lake beds, or playas. Not only do the best of these furnish a dry, hard surface with a minimum of surface irregularities, but they are also found in considerable number. Many such areas in the western United States have been investigated by AFCRL scientists during the past year.

The playas were studied for their size, local geology, seasonal variations, and surface and subsurface properties. Soil samples were collected to depths of 20 feet, and subsequent analysis determined mineral content and mechanical properties. Depths of water tables were obtained by the application of electrical-resistivity techniques. Local meteorological and climatic records were studied to obtain an estimate of terrain changes under rain and freeze conditions. Loading tests were conducted to simulate the static and dynamic loads of aircraft, and tentative aircraft-use criteria were established.

Through this research in the western United States by AFCRL scientists during the past year, many new "airfields" have been placed in the tentative-usage category. There are many areas, however, that have been identified as potential landing areas from the standpoint of size and flatness, but which cannot be used because of the poor weight-supporting properties of the soil. This has led to supplemental investigations of techniques for artificially compacting soils.

INTERSTELLAR GASES

DR. N. H. DIETER, Space Physics Laboratory, AFCRL

Although it has been known for many years that the vast distances between the stars of our galaxy are filled with gas molecules, no significant concentration of any single constituent was detected until 1951. In that year, hydrogen was identified. Since then, the mapping of hydrogen concentrations in space has become a highly active branch of astronomy itself, an activity in the category of visible and radio-star mapping. These concentrations may provide important clues to the formation and dynamics of our galaxy.

Astronomers have assumed that concentrations of gases other than hydrogen might be present; but until recently none (except for very small traces of sodium and calcium) has been found. Therefore, when radio astronomers at the Lincoln Laboratory, in October 1963, detected the hydroxyl (OH) radical in interstellar space, the discovery marked a highly significant astronomical event. The importance of this discovery touched off confirmation attempts at several radio observatories, one of these being AFCRL's Sagamore Hill Radio Observatory. Using a beam-type parametric amplifier attached to an 84-foot radiotelescope, AFCRL confirmed the existence of the hydroxyl radical. The work was carried out in November and December, 1963.

The hydroxyl radical is detected at a wave length of 18 centimeters (1667 Mcps). This spectral line may take a place of importance in radio astronomy next to that of the well-known 21-centimeter (1420 Mcps) line of hydrogen. The hydroxyl radical has been measured only in absorption spectra. To measure absorption spectra, the gas must be between a radio star and the radiotelescope. The radio star is the source of radio frequencies across a broad spectrum. Each element absorbs, or filters, certain specific frequencies. This absorption is most pronounced at a wave length of 21 centimeters for hydrogen, and 18 centimeters for the hydroxyl radical. An interstellar gas not only absorbs radio energy at a characteristic wave length, but emits radio energy at the same wave length. The emission spectra are also the signature of a particular element. Because emissions take place over large sections of the sky, emission spectra are often more difficult to measure than absorption spectra. But of course the measurement of emission spectra is not confined, as in the case of absorption spectra, in those areas of the sky where there is a radio star in the background to provide radio energy.

The work at the Sagamore Hill Radio Observatory was carried out by Dr. N. H. Dieter of AFCRL and Dr. H. I. Ewen of the Ewen Knight Corporation. (Dr. Ewen is codiscoverer of the hydrogen line.) The hydroxyl line was detected in absorption in the spectrum of the radio source, Cassiopeia A. Concurrent with the AFCRL observations, a group in Sydney, Australia, found the line in the spectrum of Sagittarius A near the center of our galaxy. Sagamore Hill observations of Sagittarius A support the Australian results in detail.

The gases--both the hydrogen and the hydroxyl radical--move at tremendous velocities. Thus, when we speak of wave lengths of 21 and 18 centimeters, we are talking of the rest wave lengths. Actual measurements on earth must be made at frequencies which account for doppler shift. (The doppler shift, it should be noted, permits us to distinguish between absorption by interstellar gas molecules and absorption by the same gas molecules in the atmosphere which absorb near the rest frequency.) One of the most interesting features of the AFCRL observations is that the hydroxyl molecules have been discovered in areas of the sky where hydrogen is absent. Thus the two gases are not always found in close association.

enigmas to codes

ROWENA W. SWANSON
Directorate of Information Sciences, AFOSR

Information-system design is concerned with developing a structure for, and describing patterns of information flow so that information meaningful to a system can be identified, acquired, and digested in accordance with the purposes of the system. System design has been largely ad hoc, cut-and-try, with portions of new systems built on experience derived from old ones. Systems based on these foundations grow ponderous, inefficient, and disorganized. Spurred by technology, acceleration in the generation and transmission of information demand systems which will not bog down under load.

Biological organisms are existence proofs of systems capable of processing vast quantities of information. How do these organisms structure their input to make it meaningful? By what selection and compression techniques does man, for example, reduce his 10^7 bits/second of sensory input to 5 to 25 bits/second, the maximum rate at which he can make decisions?[1] What are the building blocks of these organisms? How are they related? How reliable are they? How do perturbations and destruction affect performance of the organism? Can the operations of the building blocks and the organisms be mechanistically described? How could such descriptions be used in the design of information systems?

The secrets of configuration and behavior long encapsulated in biological organisms are steadily being discovered. Computable functions can be abstracted from behavior which can be logically, completely described.[2] However, a large number of systems or networks can be designed with even a small number of building blocks (e.g., 2^{400} networks with an assembly of 20 idealized neurons[3]). Must system construction thus always be by cut-and-try, or can scientific investigation disclose classes of networks more rewarding than others? We know today that biological organisms are aggregates of highly nonlinear elements, and that they survive in only particular organizational modes.[4] There is, therefore, at least a putative direct relationship between biological-system structure and function and information-system components and circuitry, with indications of approaches for formally representing their behavior.

Under an AFOSR grant,[5] a research team at the University of Illinois, Urbana, is formulating theoretical bases for abstracting networks and quantitative measures for comparing the performance of such systems. Adequate criteria must first be established for the operational modes of a system. Then expressions must be derived which adequately describe behavior and permit determination of the design parameters of the system. Circuitry and technology for realizing such systems are the next steps. Progress has been made on a theory of abstracting networks which compute certain geometric invariants in the set of all stimuli presented to the nets by introducing nonlinearity of two different kinds in the operation of the individual element. Preliminary study of "simple" complex systems, i.e., systems composed of like elements, has furnished information about the methodology for investigating the statistical behavior of such systems.

A basic element was chosen which computes a functional of four functions on its two-valued input variables. The function is determined by one of the four preceding states of its two two-valued output variables. Two important features of systems composed of such elements have been achieved: (a) retention of memory traces at the site of their action; and (b) a speeding up of computation by a factor roughly proportional to the factorial of the number of elements which are simultaneously operating and informationally linked to each other. A measure of separability, or rather, a measure of inseparability, has been introduced into the concept of a subsystem, to account for the irreducible

interactions which occur among subsystems of large systems.

At the heart of this research, however, is the attempt to establish fundamental principles basic to meaningful future exploration in this field. The crux of the problem has been stated in a recent paper by Professors W. Ross Ashby and Heinz von Foerster:

> For living organisms to survive, they must, in essence, crack the code of their environment's intrinsic order. This they have accomplished if they can form an internal representation of the order of their surroundings. Although, at first sight, these considerations appear to be almost trivial, they provide us with an important clue as to some of the principles of the internal organization of living systems: since we are aware of many of nature's intrinsic laws, we have to search for the code in which these laws represent themselves within our enigmatic systems.[6]

The aim is to establish a modern theory of mechanism, unbounded in complexity, both with respect to numbers of working parts and conditionalities governing their internal activities. As biological organisms are products of evolutionary processes, so a complex mechanism might be expected to be derived through a step-wise development. Professor Ashby envisions that the "property of reacting to combinations and relations between stimuli, is readily obtained from mechanism, if the mechanism works in stages or levels so that the first level 'computes' various functions of the primary stimuli, then the later levels compute functions of these functions, and the final stage acts only if these 'computational' processes have resulted in some actual physical event at the penultimate stage."In this way," he continues, "any defined function over the primary stimuli, however complex or subtle it may be, can be transformed, in a purely mechanistic way, to a physical event suitable to act as a physical cause for the action."[7] Toward the development of this theory, Professor Ashby states three propositions:

1. The modern theory of mechanism is founded on the concept of a mapping which underlies and drives events shaped to homeostatic form by natural selection.

2. The modern theory of mechanism, by considering cause-effect relations in great numbers (both in long sequences and with feedback), provides a technique and logic adequate for the complex facts of biology and psychology.

3. The modern theory of mechanism is fundamentally a logic of behavior (not of matter or of energy).[8]

The general study of complex dynamic systems reacting with a complex environment has only just begun. Over the past thirty years, much understanding has been gained of complex biological systems and the design and construction of mechanical control systems. The "New Mechanist," as Professor Ashby calls him, now has at his disposal the data and materials against which to test his mathematics and logic. It is his task to build a new bridge for science, spanning the gap between neuron and information system.

References:

1. Barlow, H.B., "Evidence Apparently Related to Information-Processing and Behavioral Correlates," Information Processing in Neurones and Small Nets, Anatol Rapoport and William J. Horvath, eds. WADD Tech. Rept. 60-652, pp 365-400, Dec. 1960.

2. Pitts, Walter, and Warren S. McCulloch, "How We Know Universals, the Perception of Auditory and Visual Forms," Bull. Mathematical Biophysics, vol. 9, no. 3, pp 127-147, Sept. 1947.

3. Ashby, W. Ross, and Heinz von Foerster, "Biological Computers," Bioastronautics, Karl E. Schaefer, ed. London, MacMillan Book Co., Ltd., 1963.

4. Ibid.

5. AFOSR Grant 7-63.

6. Ref. 3, p. 8.

7. Ashby, W. Ross, "The Behaving Organism," The Biological Basis of Pediatric Practice, R.E. Cooke, ed. New York: Grune and Stratton, in press.

8. Ibid.

Schedule of Scientific Symposia

20-23 April 1964	SEMINAR ON NONLINEAR PARTIAL DIFFERENTIAL EQUATIONS IN MATHEMATICAL PHYSICS, at New York University, New York, NY. Cosponsors: AFOSR, Army Research Office (ARO), American Mathematical Society (AMS). For information contact Dr. R. G. Pohrer, AFOSR (SRMM), Tel: OX 6-5248. UNCLASSIFIED
22-25 April 1964	FOURTH RARE-EARTH RESEARCH CONFERENCE, at Phoenix, Ariz. Sponsor: AFOSR. For information contact Lt Col M.D. Sprinkel, AFOSR (SRC), Tel: OXford 6-8705, or Program Director, Dr. LeRoy Eyring, Dept of Chemistry, Arizona State University, Tempe, Ariz. UNCLASSIFIED
11-14 May 1964	SYMPOSIUM ON APPLIED MATHEMATICS & MECHANICS IN HONOR OF THEODORE VON KARMAN, Washington, D.C. Cosponsors: AFOSR and Society for Industrial & Applied Mathematics. For information contact Maj B.S. Morgan, Jr., AFOSR (SRMA), Tel: OX 6-1302. UNCLASSIFIED
8-10 June 1964	FOURTEENTH MRI SERIES SYMPOSIUM, "QUASI OPTICS," at Statler Hilton Hotel, New York, NY. Cosponsors: AFOSR, ARO, Office of Naval Research (ONR). For information contact Lt Col W.C. Athas, AFOSR (SREE), Tel: OXford 6-3671. UNCLASSIFIED
22-27 June 1964	INTERNATIONAL BIOPHYSICS MEETING, at Paris, France. Cosponsors: AFOSR, International Organization for Pure & Applied Biophysics, and National Academy of Sciences. For information contact Capt B.D. Stollar, AFOSR (SRLA), Tel: OXford 6-4181. UNCLASSIFIED
22-24 June 1964	INTERNATIONAL CONFERENCE ON PHOTOSENSITIZATION IN SOLIDS, at Illinois Institute of Technology, Chicago, Ill. Cosponsors: AFCRL, ONR, Space Physics Laboratory, and Illinois Institute of Technology. For information contact T.K.Mukherjee, AFCRL (CRFE), Tel: Ext 3227. UNCLASSIFIED. Attendance by invitation only.
June 1964	SYMPOSIUM ON QUANTITATIVE BIOLOGY, at Cold Spring Harbor, NY. Cosponsors: AFOSR and Cold Spring Harbor Laboratory of Quantitative Biology. For information contact Capt B.D. Stollar, AFOSR (SRLA), Tel: OXford 6-4181. UNCLASSIFIED
6-9 July 1964	LEARNING & ASSOCIATED PHENOMENA IN INVERTEBRATES, at Cambridge University, Cambridge, England. Cosponsors: AFOSR, ONR, National Science Foundation (NSF), American Society of Zoologists, and British Association for the Study of Animal Behavior. For information contact Dr. R.V. Brown, AFOSR (SRLA), Tel: OXford 6-4181. UNCLASSIFIED
6-31 July 1964	1964 SUMMER RESEARCH INSTITUTE ON ALGEBRAIC GEOMETRY, at Whitney Estate, Woods Hole, Mass. Cosponsors: AFOSR, NSF, AMS, North Atlantic Treaty Organization. For information contact Dr. R.G. Pohrer, AFOSR (SRMM), Tel: OXford 6-5248. UNCLASSIFIED. Attendance by invitation only.
6-11 July 1964	CONCENTRATED VORTEX MOTIONS IN FLUIDS, at University of Michigan, Ann Arbor, Mich. Cosponsors: AFOSR, ONR, NSF, National Aeronautics and Space Administration (NASA), and International Union of Theoretical and Applied Mechanics. For information contact Maj W.B. Terrell, AFOSR (SREM), Tel: OXford 6-3425. UNCLASSIFIED. Attendance by invitation only.

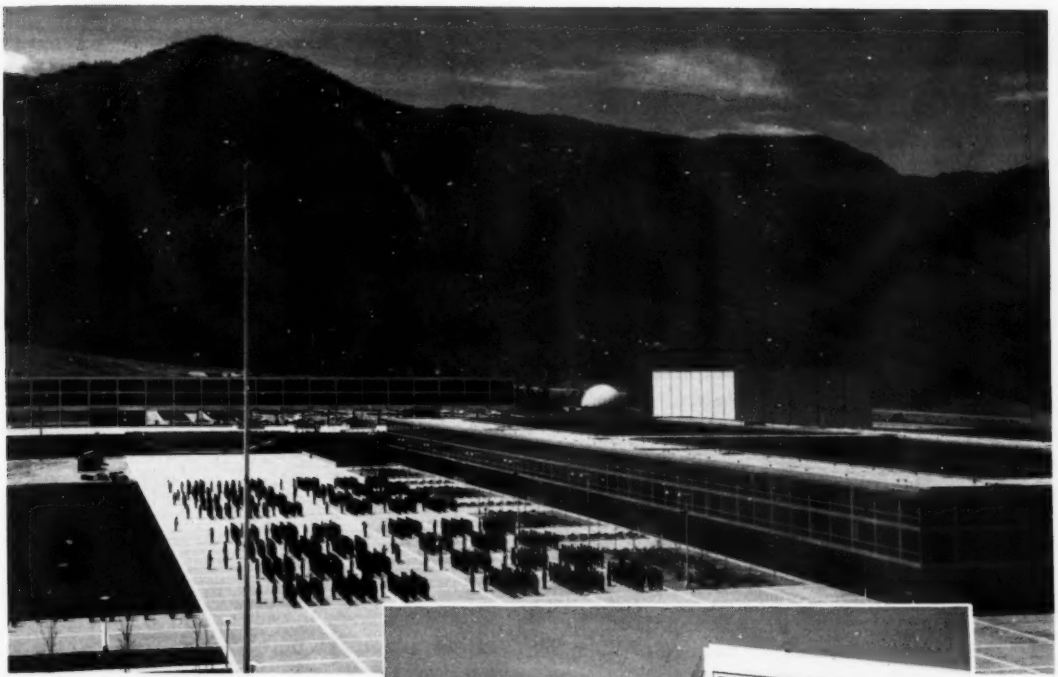
Two of OAR's World-Wide Installations

CHURCHILL RESEARCH RANGE

Ft. Churchill, Canada

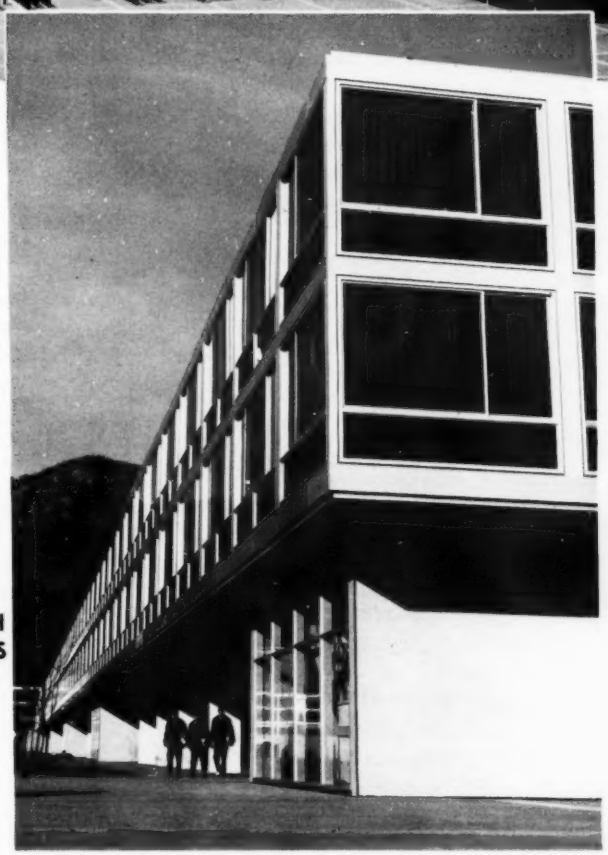
VIEW OF AN AEROBEE LAUNCH TOWER

LAUNCHING OF AN ARCAS RESEARCH ROCKET AT FORT CHURCHILL



MILITARY FORMATION AT THE AIR FORCE ACADEMY

FRANK J. SEILER RESEARCH LABORATORY USAF Academy Colorado



THE FRANK J. SEILER RESEARCH LABORATORY IS LOCATED IN THIS BUILDING AT THE ACADEMY

PHILOSOPHY and STATE-of-the-ART of LEARNING CONTROL SYSTEMS

MAJOR BERNARD S. MORGAN, JR.
Applied Mathematics Division, AFOSR

Nowadays almost everyone is learning about learning. So, too, is the Applied Mathematics Division of AFOSR which is supporting Professor John Gibson of Purdue University in a research program in Adaptive Automatic Control and Learning Systems. One of the results of this program has been the publication of an AFOSR technical report, AFOSR 5144, entitled, "Philosophy and State-of-the-Art of Learning Control Systems," by Professor Gibson and his colleagues.

The report presents an objective and theoretical introduction to the use of learning in control systems. It is divided into three parts. In the first part, the relevant aspects of the psychology of learning and some of the classical concepts of machine learning are treated. The latter includes an excellent summary on the theories of the simulation of animal nervous systems by artificial neurons interconnected in neural networks.

In the second part, learning is defined and its relation to the concept of adaptive control is presented. The view here on the possible application of learning theory to control-system design differs from conventional learning studies in one rather important respect. Conventional learning systems proposed in the literature, even when applied to control situations, are open loop. The learning process proceeds in two steps. First, an off-line training sequence and, following this, an on-line operation. The off-line training is tedious and, at its conclusion, the learning system is saturated, that is, no further learning takes place.

Professor Gibson, however, views learning only as an on-line function with no off-line training permitted. Such a modification is made possible by utilizing two features of control-system operation not present in previous learning-system studies. First and most important is the inclusion in the system of an adaptive control operation. When the system begins, it operates as an adaptive system and learns on-line as it goes. Second is the calculation of an index of performance during the operation. The system proceeds to minimize (or maximize) the index of performance by application first of adaptive techniques and then learning. The details of how this is accomplished is the subject of the third part of the report where several different learning control systems are treated.

SLOWING WARM-UP RATES OF DEWAR SYSTEMS

PETER D. GIANINO, Solid State Sciences Laboratory, AFCRL

When we lower the temperature of an electronic material--ruby, silicon, ferrite, and so on--its electrical behavior can change drastically. Much research in solid-state materials is therefore devoted to the low-temperature performance of materials.

Analysis of the performance of electronic materials as a function of temperature requires that temperatures remain relatively stable over a sufficient period of time to permit precise measurements. For extremely low temperatures, this entails the use of Dewar flasks. (Dewar flasks use the same vacuum, heat-reflective mirror glass principle as the thermos bottle to maintain temperature.) A double Dewar system is simply one such flask inside another.

Temperatures of special interest in research laboratories fall within the interval of 4.2 degrees K of liquid helium and 77

degrees K of liquid nitrogen. These two liquids are most commonly used in double Dewar systems, liquid helium in the inner container, liquid nitrogen in the outer. But within conventional systems, temperatures will ordinarily rise at the rate of about 60 degrees an hour. The experimentalist would like to see this rate reduced.

With this by way of background, Peter D. Gianino of AFCRL has developed a method for reducing the time rate of change of temperature within a glass double Dewar system from the normal rate of about 60 degrees to about 5 to 10 degrees an hour. The technique involves nothing more than inserting a small amount of activated charcoal in the inner Dewar which contains the liquid helium. This reduction in the time rate of change of temperature allows ample time for a multitude of measurements within very small temperature intervals.

Although steady temperatures above 4.2 degrees K can be achieved by maintaining a constant rate of evacuation of the desorbed helium gas by means of a vacuum pump, precision in pumping rates is difficult to maintain, and thus add another parameter to the experiments which must be closely controlled. The charcoal method has the advantage of extreme simplicity.

This effect can be explained in the following manner: the liquid helium, which cools the apparatus down to 4.2 degrees K, is absorbed by the charcoal. Upon disappearance of the liquid, any heat leaking in is used to desorb the helium gas from the charcoal and to overcome the charcoal's high heat capacity. The temperature, therefore, rises very slowly. The effect becomes much more pronounced as temperature rises, since the specific heat of charcoal, as well as that of the glass, increases with increasing temperature.

Mr. Peter D. Gianino, a physicist with the Solid State Sciences Laboratory, AFCRL, is presently engaged in research on ferromagnetic resonance studies at all temperatures--magnetic anisotropy, crystal structure and X-ray techniques. He received his degree of B.S. in Physics, Cum Laude, in 1953, and his M.S. degree in Math-Physics from Northeastern University in 1959. He is now studying for his PhD in physics at Tufts University.

OAR Profiles

This photo shows two AFCRL scientists, Mr. John Mott-Smith on the left, and 1st Lt Ronald J. Massa on the right. Both are with the Data Sciences Laboratory, and are engaged in research aiming at the reduction of the band width required to transmit television pictures. This would make more channels available on the radio-frequency spectrum, and permit the transmission of TV pictures over much greater distances with the same amount of power. The specialized data processing equipment used in their work is shown in the photo.

1st Lieutenant John A. Decker, Jr., a scientist with the Plasma Physics Research Laboratory, ARL, is currently doing research in plasma physics, and is working on the design, construction and preliminary check-out of a large quiescent plasma facility. This facility is to provide a low-temperature cesium plasma, contained by a strong magnetic field and generated by resonance ionization at hot tungsten plates, for use in research on plasma stability and wave propagation in plasmas. Previously, Lt Decker conducted research into the properties of a low-pressure cesium arc in the presence of a strong magnetic field at Cambridge University. He is now writing his PhD thesis on this work. He also has a B.Sc. in Aeronautical Engineering (1958) and a "Degree of Aeronautical Engineer" (1958), both from MIT. Lt Decker has formerly worked with the Aeroanalysis Group, Convair, Fort Worth, Texas; Naval Supersonic Lab, MIT; Aerodynamics Research Group, Sandia Corp., Albuquerque, New Mexico; and the Engineering Research Lab, North American Aviation, Inc. Los Angeles, Calif.

Dr. Nannielou H. Dieter, a mathematician with the Space Physics Laboratory, AFCRL, is currently considering problems of radio emission from remnants of supernova explosions. She is also a research associate at Harvard College Observatory. In her article in this issue, "Interstellar Gases," she writes about AFCRL's recent work in measuring the hydroxyl radical in interstellar space at the Sagamore Hill Radio Observatory. Shown in the background of the photo is the 84-foot telescope used for these measurements. Dr. Dieter received a B.A. in mathematics (1948) from Goucher College, becoming Phi Beta Kappa in her senior year. She received her M.A. degree from Harvard University-Radcliffe College in 1957 and her PhD degree in 1958. In 1948, she was a mathematician with the U.S. Coast and Geodetic Survey, and in 1951 joined the Radio Astronomy Branch of the Naval Research Laboratory. In 1958, Dr. Dieter was awarded a National Science Foundation post-doctoral fellowship for the study of the neutral hydrogen radiation from the Andromeda Nebula. She has been at L G Hanscom Field since 1958.

Mr. Owen W. Williams is Chief of the Terrestrial Sciences Laboratory, AFCRL. He is now engaged in work on satellite geodesy, rocket-flash triangulation, long-line azimuth determinations, etc. Many of his innovations are being formulated into new techniques and approaches to the general problem of obtaining more precise data on the size and shape of the earth. Mr. Williams received his B.A. degree with honors from Kalamazoo College in 1948. From 1948-1950, he attended the George Washington University Graduate School, and in 1957 attended a special graduate course in electronic surveying at the Geodätisches Institut, Technische Hochschule in München, Germany. Mr. Williams served with the Navy in the Pacific Theater during World War II, after which, from 1948-1955, he was employed as a geodesist and Military Intelligence Research Specialist with the Army Map Service. From 1955-1957, he was Assistant Chief and Chief of the Geoscience Branch, Aeronautical Chart and Information Center. He has been with AFCRL (formerly AFCRC) from 1957 to the present. His current contribution to this issue of the Review is on "Natural Operating Areas for Aircraft."

to our readers

Requests for further information should be directed to the individual or laboratory of origin (except for those from Latin America).

Addresses are as follows:

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AEROSPACE RESEARCH LABORATORIES
Attn: ARB
Wright-Patterson Air Force Base, Ohio 45433

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
Attn: SRGL
Tempo D Building
4th and Independence Avenue, S.W., Washington, D C. 20333

OFFICE OF RESEARCH ANALYSES
Attn: ORR
Holloman AF Base, New Mexico 88330

Requests for further information from institutions and individuals in Latin America should be addressed to:

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